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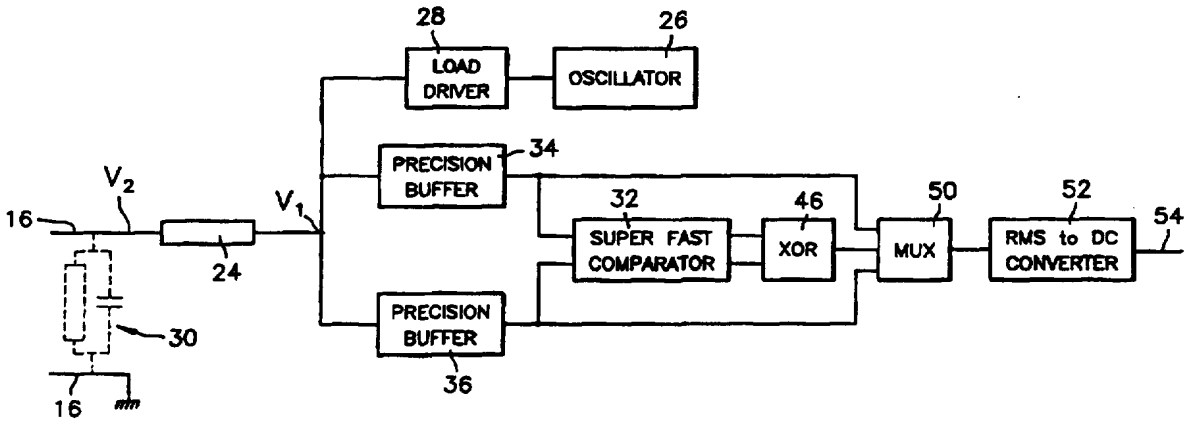
(54) Title: DETERMINING THE DIELECTRIC PROPERTIES OF WOOD




(57) Abstract

The dielectric properties of wood (12) in a wood-drying kiln (10) is determined by having the wood disposed between electrodes (16), applying a sinusoidal voltage (38) to the electrodes via a resistive element (24), determining the phase angle ($\omega$) between the applied voltage ($V_1$) and the voltage ($V_2$) across the electrodes and the magnitude of these voltages, and determining from these values the phase angle and magnitude of the complex impedance between the electrodes.

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# -- DETERMINING THE DIELECTRIC PROPERTIES OF WOOD --

This invention relates to a method of determining the dielectric properties of wood, in particular for purposes of deriving therefrom a measure of the moisture content of the wood, and to means for use in such method.

The moisture content of wood can be expressed as the difference between the wet weight and the dry weight of the wood, divided by the dry weight.

When drying wood in a wood drying kiln, an end-point moisture content of 5% to 20% is normally required. Traditional methods of measuring the moisture content of wood, whilst reasonably accurate towards the end-point moisture content, become less accurate at higher values of the moisture content. At a moisture contents of above 30%, the traditional methods become completely unreliable.

For the proper control of the environment in which wood is dried, for example, in a wood-drying kiln, it is important for the moisture content of the wood to be known accurately while the moisture content is still relatively high, e.g. above 30%. If the moisture content is accurately known at these relatively high values it becomes possible to accelerate the drying process considerably, without causing undue stresses in the wood.

According to the present invention there is provided a method of determining the dielectric properties of wood, which method includes having the wood disposed between electrodes, applying a varying

electrical signal to the electrodes, measuring the electrical values of the signal, and determining from the measured values the phase angle and magnitude of the complex impedance between the electrodes.

The varying electrical signal can conveniently be a sinusoidal voltage and can be applied to the electrodes via a resistive element, and the phase angle between the applied voltage (i.e. the voltage before the resistive element) and the voltage across the electrodes (i.e. the voltage after the resistive element), and the magnitudes of said voltages determined. From this it is possible to derive the phase angle and magnitude of the complex impedance between the electrodes.

It will be understood that one of the electrodes may be ground, i.e. the structure on which the wood is supported, where the structure is of an electrically conductive material.

The measured values may be determined in an electronics module which is in close proximity to the electrodes, and the phase angle and magnitude of said complex impedance may be determined from the measured values in data processing means which is remote from the electrodes, there being a data link between the electronics module and the data processing means.

Further according to the invention there is provided means for determining the dielectric properties of wood, which comprises a pair of electrodes between which the wood can be disposed, and means for determining the phase angle and magnitude of the complex impedance between the electrodes.

Still further according to the invention

there is provided a wood-drying installation which comprises a wood-drying kiln and means for determining the moisture content of wood being dried in the kiln, said means comprising a pair of electrodes between which the wood in the kiln can be disposed, and means for determining the phase angle and magnitude of the complex impedance between the electrodes.

The means for determining the phase angle and magnitude of the complex impedance between the electrodes may comprise a resistive element connected in series with one of the electrodes, means for applying a sinusoidal voltage to the electrodes via the resistive element, and means for determining the phase angle between the applied voltage and the voltage across the electrodes and the magnitudes of said voltages.

The invention will now be described in more detail, by way of example, with reference to the accompanying diagrammatic drawings.

In the drawings:

Figure 1 is an end view of a stack of timber, in a wood drying kiln provided with measuring means in accordance with the invention;

Figure 2 is a block diagram of the measuring means;

Figure 3 shows certain voltage waveforms; and

Figure 4 is a phasor diagram of the voltages.

Referring now the drawings in more detail, reference numeral 10 indicates a wood-drying kiln in which there is a stack of timber 12. The timber 12 is arranged in layers which are spaced from one another by means of spacers. The environment inside the kiln is controlled according to the moisture content of the

timber.

To determine the moisture content of the timber accurately, the kiln is provided with measuring means comprising an electronics module 14 outside but in close proximity to the kiln, a pair of electrodes 16 inside the kiln and coupled to the module 14 by means of electrical connections 18, and a remote data processor 20 which is connected to the electronics module 14 by means of a data link 22. Where there are a number of kilns 10, each with its own electronics module 14, the various electronics modules may all be connected to the same data processor 20.

The electrodes 16 are in the form of metal plates and are simply inserted into the spaces between layers in the stack 12. It is an important feature of the invention that the electrodes 16 need not be cleaned prior to insertion into the stack, as operation of the apparatus is not affected by the degree of physical contact with the timber. The size and exact position of the electrodes is also not important. If the size and/or position of the electrodes is changed, all that will be required is for the system to be recalibrated.

The electronics module 14 serves to measure the values that are required to determine the phase angle and magnitude of the complex impedance between the electrodes 16. This is achieved in the following manner. The electronics module 14 includes a resistive element 24, connected in series with one of the electrodes, and an oscillator 26 and associated driver 28 whereby a sinusoidal voltage can be applied to the electrodes via the resistive element. The oscillator 26 has a frequency which is in the ultra-sonic range, for example in the order of 40kHz. The impedance

indicated at 30 represents the impedance between the electrodes 16.

The electronics module 14 further comprises a super-fast comparator 32 which is connected via a precision buffer 34 to the output of the driver 28, and via a precision buffer 36 to one of the electrodes, the other electrode being connected to ground.

The waveform of the applied voltage (i.e. the output of the driver 28) is indicated at 38 in Figure 3, whereas the waveform of the voltage across the electrodes 16 (i.e. after the resistive element 24) is indicated by reference numeral 40 in Figure 3. In Figure 4 the applied voltage 38 is indicated by the phasor $V_1$ and the voltage across the electrodes by the phasor $V_2$. Because the impedance 30 is a complex impedance, there is a phase difference between the voltages $V_1$ and $V_2$, this being indicted by the angle $\omega$ in Figure 4. $V_x$ in Figure 4 is the voltage across the resistive element 24.

The comparator 32 serves to convert the sinusoidal voltages 38 and 40 to square-wave voltages 42 and 44 respectively.

The electronics module 14 further comprises an exclusive OR (XOR) circuit 46 whose output is indicated at 48 in Figure 3. The RMS value of the output 48 varies in proportion to the phase difference between the voltages 38 and 40. The outputs of the buffers 34 and 36 and the output of the XOR circuit 46 are fed via a multiplexer 50 to an RMS-to-DC converter 52. The multiplexer 50 has a relatively slow sampling rate as compared with the frequency of the applied signal.

Output 54 of the RMS-to-DC converter 52 is relayed to the data processor 20 via the data link 22.

The phase angle of the impedance 30 is determined by making use of the following equations:

$$a = V_2 * \cos \omega$$

$$b = V_2 * \sin \omega$$

$$d = V_1 / \{-a * (a/b - b)\}$$

$$c = a * d / b$$

$$C_x = d / \{R * 2\pi f\}$$

$$R_x = R / (c-1)$$

Where:

- $V_1$ is the amplitude of the applied voltage;
- $V_2$ is the amplitude of the voltage across the electrodes;
- $\omega$ is the phase difference between the voltages $V_1$ and $V_2$;
- $R$ is the series resistive element 24;
- $f$ is the frequency of the applied voltage;
- $C_x$ is the value of the capacitive component of the complex impedance 30; and
- $R_x$ is the resistive component of the complex impedance 30.

assuming that the capacitive and a resistive components of the impedance are in parallel.

In the event that the complex impedance includes an inductive component ($L_x$) in parallel with the capacitive component $C_x$, the value of $L_x$ can be determined independently from $C_x$ by measuring the complex impedance at two different frequencies.

It will be appreciated that other methods can

be used to determine the phase angle and magnitude of the complex impedance 30.

The moisture content of the timber is derived by suitable data processing in the data processor 20.

CLAIMS:

1. A method of determining the dielectric properties of wood, **characterised in that** it includes the steps of having the wood (12) disposed between electrodes (16), applying a varying electrical signal to the electrodes, measuring the electrical values of the signal, and determining from the measured values the phase angle and magnitude of the complex impedance between the electrodes.

2. A method as claimed in claim 1, **characterised in that** the varying electrical signal is a sinusoidal voltage (38) applied to the electrodes (16) via a resistive element (24); and that the measured values are the phase angle ($\omega$) between the applied voltage ($V_1$) and the voltage across the electrodes ($V_2$), and the magnitudes of said voltages.

3. A method as claimed in claim 2, **characterised in that** the measured values are determined in an electronics module (14) which is in close proximity to the electrodes; and that the phase angle and magnitude of said complex impedance is determined from the measured values in data processing means (20) which is remote from the electrodes; there being a data link (22) between the electronics module and the data processing means.

4. Measuring means for determining the dielectric properties of wood, **characterised in that** it comprises a pair of electrodes (16) between which the wood (12) can be disposed, and means (14, 20) for determining the phase angle and magnitude of the complex impedance between the electrodes.

5. A wood-drying installation which comprises a

wood-drying kiln (10) and means for determining the dielectric properties of wood (12) being dried in the kiln, **characterised in that** said means comprises a pair of electrodes (16) between which the wood in the kiln can be disposed, and means (14, 20) for determining the phase angle and magnitude of the complex impedance between the electrodes.

6. A wood-drying installation as claimed in claim 5, **characterised in that** the means for determining the phase angle and magnitude of the complex impedance between the electrodes comprises a resistive element (24) connected in series with one of the electrodes (16), means (26, 28) for applying a sinusoidal voltage (38) to the electrodes via the resistive element, and means (34..46) for determining the phase angle ($\omega$) between the applied voltage ($V_1$) and the voltage ($V_2$) across the electrodes and the magnitudes of said voltages.

7. A wood-drying installation as claimed in claim 6, **characterised in that** the resistive element (24) and means (34...46) for determining the phase angle ($\omega$) between the applied voltage ($V_1$) and the voltage ($V_2$) across the electrodes and the magnitudes of said voltages form part of an electronics module (14) which is in close to the electrodes; and in that it further comprises data processing means (20) which is remote from the electrodes, for determining from the measured values the phase angle and magnitude of said complex impedance; there being a data link (22) between the electronics module and the data processing means.

8. A method of determining the dielectric properties of wood, substantially as herein described and illustrated.

9. Measuring means for determining the dielectric properties of wood, substantially as herein described and illustrated.

10. A wood-drying installation, substantially as herein described and illustrated.

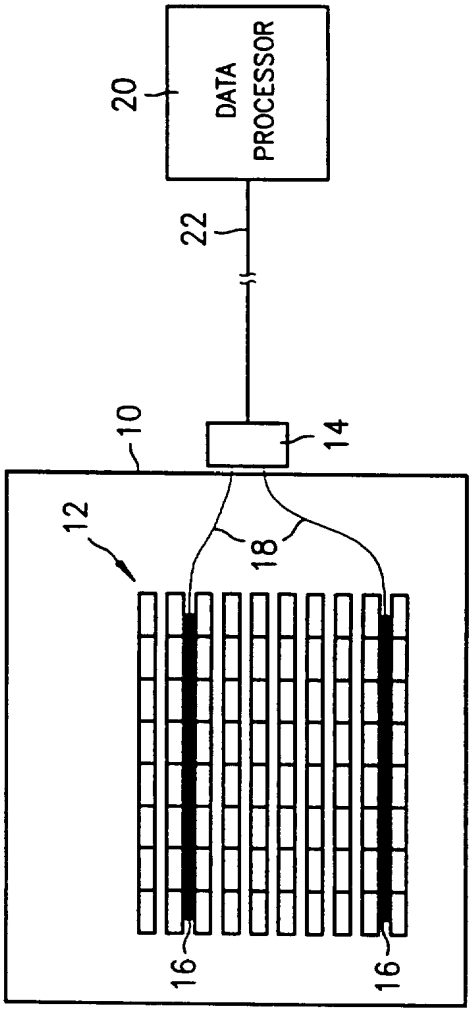
20
DATA PROCESSOR
22
10
14
12
18
16
16

FIG 1

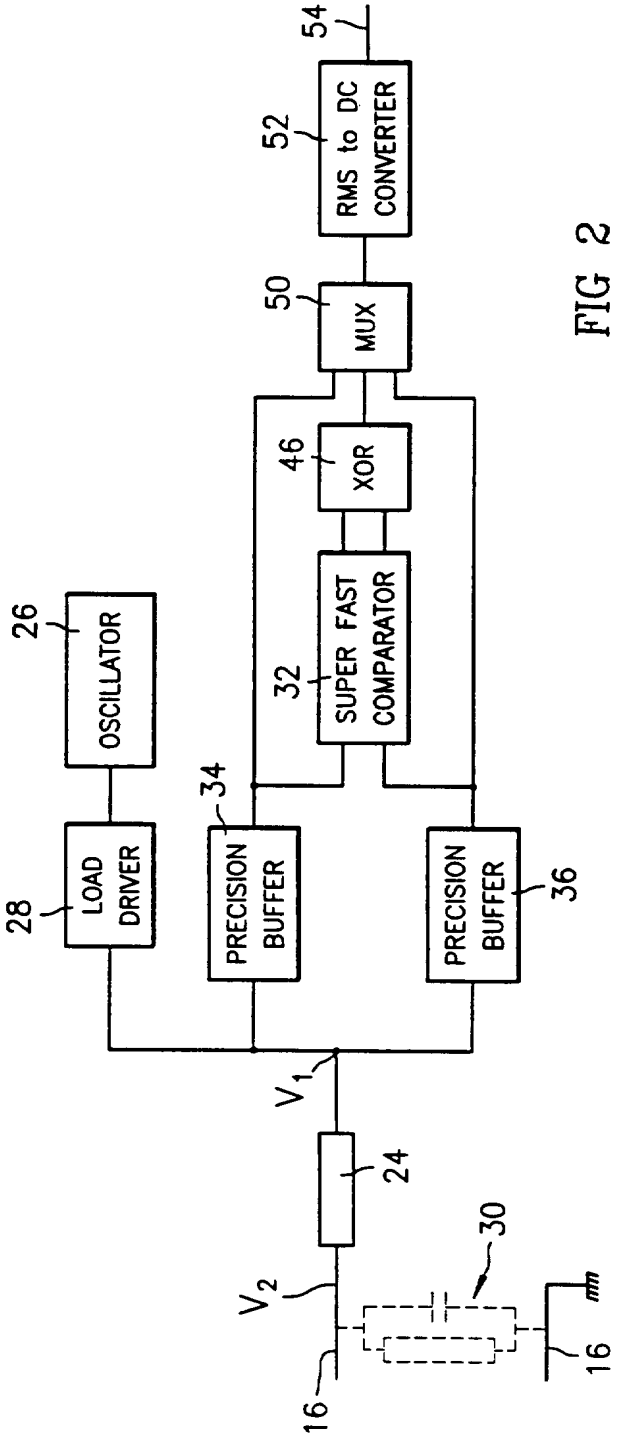
54
52
RMS to DC CONVERTER
50
MUX
46
XOR
32
SUPER FAST COMPARATOR
26
OSCILLATOR
34
28
LOAD DRIVER
PRECISION BUFFER
PRECISION BUFFER
36
V1
24
30
V2
16
16

FIG 2

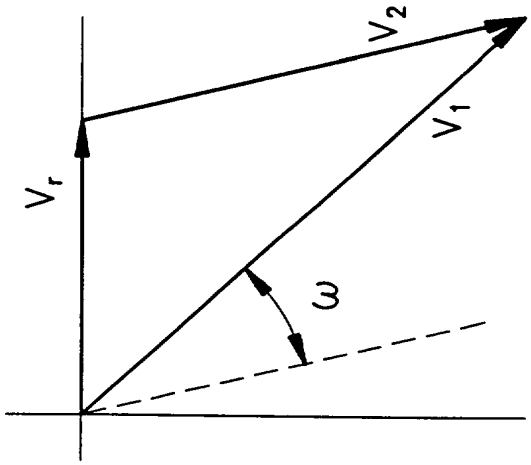


FIG 4

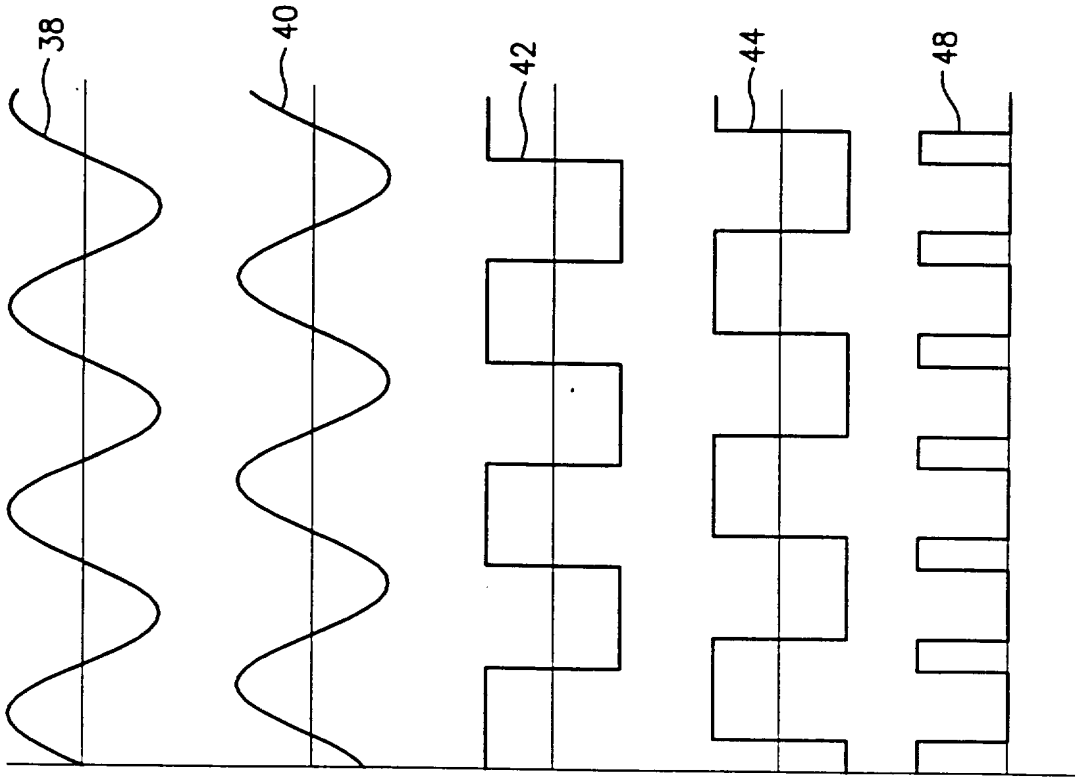


FIG 3

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/03604

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :G01R 27/02
US CL :324/664,683

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 324/664, 683

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS
Search Terms: Wood^ (Dried or Dry)^ 324/Clas ^ phase

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US, A, 3,992,665 (PREIKSCHAT), 16 November 1976, see entire text. | 1-7 |
| A | US, A, 4,181,881 (PREIKSCHAT), 01 January 1980, see entire text. | 1-7 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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| Date of the actual completion of the international search<br>22 APRIL 1996 | Date of mailing of the international search report<br>27 AUG 1996 |
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Form PCT/ISA/210 (second sheet)(July 1992)★

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/03604

**Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)**

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 8-10
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

Claims 8-10 do not have means or steps properly defined. These claims are omnibus in nature as the phrase "substantially herein described" provides no meaningful limitations in order to determine an appropriate field of search.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

**Remark on Protest**

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.